DOCUMENT RESUME

ED 395 568 IR 017 880

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TITLE Using Computer Simulations To Enhance Conceptual Change: The Roles of Constructivist Instruction and Student Epistemological Beliefs.

PUB DATE 96

NOTE 6p.; Paper presented at the Annual Conference of the American Educational Research Association (New York, NY, April 8-12, 1996).

PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.

DESCRIPTORS Anatomy; *Cognitive Development; Cognitive Structures; College Students; *Computer Simulation; *Concept Formation; *Constructivism (Learning); *Epistemology; Higher Education; Physiology; *Student Attitudes

ABSTRACT

The objectives of this study were to: examine the potential interaction between students' epistemological beliefs and placement in a simulation condition (constructivist versus non-constructivist) on conceptual development; and to assess whether a constructivist computer simulation experience would result in a greater degree of conceptual change than a non-constructivist simulation experience. The sample consisted of approximately 250 non-biology majors enrolled in a human anatomy and physiology survey course at a large midwestern university. Fourteen sections of approximately 15 students each were randomly assigned to one of two conditions: (1) a confirmatory simulation condition in which students used a cardiovascular simulation in prescribed steps to resolve a set of 12 cases or; (2) an exploratory simulation condition in which the same cardiovascular simulation was used in a constructivist setting. Students with greater epistemological sophistication were found to do better in the exploratory simulation environment while students with less sophisticated beliefs about knowledge and learning achieved best in the more prescribed, confirmatory simulation environment. Additionally, this study provided evidence that an exploratory (constructivist) simulation experience could be more effective in altering learners' misconceptions than a confirmatory experience. (Contains 19 references.) (AEF)

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Using Computer Simulations to Enhance Conceptual Change:

The Roles of Constructivist Instruction and Student Epistemological Beliefs.

by Mark Windschitl

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IR017880

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Using Computer Simulations to Enhance Conceptual Change: The Roles of Constructivist Instruction and Student Epistemological Beliefs

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• ***Objectives:*** The first objective of this study was to examine the potential interaction between students' epistemological beliefs and placement in a simulation condition (constructivist vs. non-constructivist) on conceptual development. The second objective was to assess whether a constructivist computer simulation experience would result in a greater degree of conceptual change than a non-constructivist simulation experience.

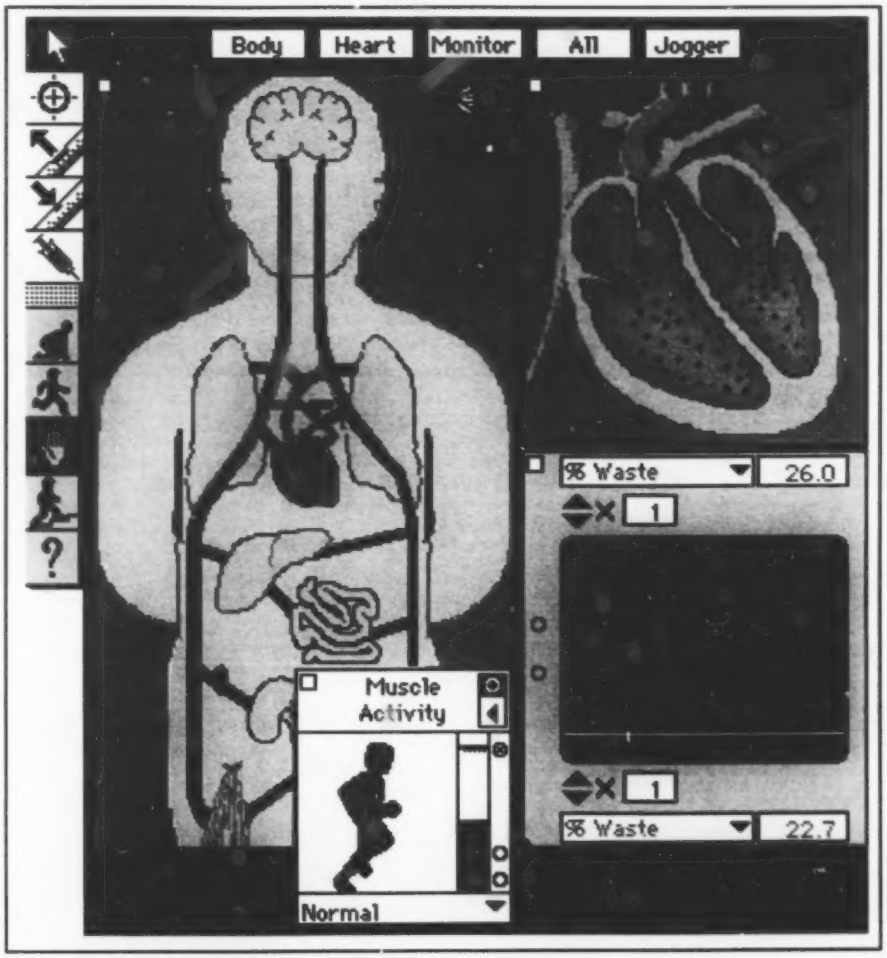
• ***Theoretical framework:*** Learners' alternative conceptions (alternative to scientific conceptions) have been described in areas such as the human cardiovascular system (Arnaudin & Mintzes, 1986), electric circuits (Dupin & Johsua, 1987), and simple mechanics (Viennot & Rozier, 1994). These alternative conceptions often have tremendous explanatory power in the mind of the student, making such conceptions highly resistant to change (Driver & Easley, 1978; Hewson & Hewson, 1983; Pines, 1985). Conditions that promote conceptual change have been described as follows: 1) learner *dissatisfaction* with an existing conception, 2) *intelligibility* of the new conception 3) *plausibility* of the new conception, and 4) *fruitfulness* or predictive power of the new conception (Hewson, 1981; Hewson & Hewson, 1983; Hewson & Thorley, 1989).

Studies have also shown that motivational beliefs (goals, values, self-efficacy, and control beliefs) play a major role in conceptual change (Pintrich, Marx, & Boyle, 1993; West & Pines, 1983; Dweck, 1986; Entwistle, Entwistle, & Tait, 1993). Kruglanski (1989, 1990) suggested that a learner's motivation toward knowledge as an object (epistemic motivation) influences knowledge acquisition. Learners' epistemological beliefs and the idiosyncratic way they view phenomena lend support to the theory of cognitive constructivism, the idea that learners "construct" their own knowledge.

Constructivist instructional approaches have incorporated the use of computer simulations to enhance conceptual development and conceptual change with mixed results. Significant results using simulations to overcome alternative conceptions in science have been reported in the area of physics instruction (Zietsman and Hewson, 1986; Gorsky & Finegold, 1992), but other findings (with electrical circuit simulations) have been non-significant (Carlsen & Andre, 1992). Given the potential for students to display and manipulate phenomena within a computer simulation, and the individualistic construction of knowledge by learners (influenced by epistemological beliefs as well as other psychological characteristics), it is appropriate to investigate how these phenomenon interact in an instructional setting.

• ***Sample:*** The sample consisted of approximately 250 non-biology majors at a large midwestern university. These students were enrolled in a human anatomy and physiology survey course in the spring semester of 1995.

• ***Design:*** Fourteen sections of approximately 15 students each were randomly assigned to one of two conditions: 1) a confirmatory simulation condition in which students used a cardiovascular simulation in prescribed steps to resolve a set of 12 cases, or,



2) an exploratory simulation condition in which the same cardiovascular simulation was used in a constructivist setting. Exploratory group students used a thematic instructional guide to hypothesize about and test possible resolutions to the same 12 cases used by the confirmatory group. Figure 1 (on back page) illustrates the differences between parallel cases for the exploratory and confirmatory groups. The 12 cases dealt with topics identified through a pilot study and through related literature as being subject to alternative conceptions by learners.

• ***Instruments***: A 63-item epistemological survey measuring subjects' beliefs about learning was given along with a 24-item multiple choice pretest on the human cardiovascular system. The posttests were a 30-item multiple choice instrument and a 22-item concept-comparison instrument designed to measure the students' understanding of the strength of relationship between pairs of concepts. The concept comparison was developed to furnish a second type of measure for conceptualization and to contribute to knowledge in the area of alternative assessment types.

A computer simulation that modeled the functioning of the human cardiovascular system was used for this study. The simulation presented the user with windows, one of which contained buttons that could be selected to display dynamic information in multiple forms such as line graphs, bar graphs, or pie graphs. The second window contained a transparent frontal view of the human circulatory system, a transparent frontal view of the heart, and a small animated figure that could be made to rest, walk, or run by the user.

• ***Procedure***: In Week 1, all subjects were briefly shown the cardiovascular simulation in their laboratory class. All subjects also completed the epistemological survey and multiple choice pretest. In Week 2, students met during regular class times in a nearby computer lab. With the subjects working individually, they were given time to practice using the simulation. The *confirmatory* group was given a written guide with specific instructions to follow in manipulating the software. Over the next two laboratory class periods the students attempted to resolve 12 "cases". The students had few options for exploration; they were prompted to select appropriate parameters to adjust in order to be presented with evidence that refuted commonly held misconceptions about aspects of the cardiovascular system. Individuals in the *exploratory* group were required to explicitly state a prediction about certain phenomena within the cases (the same 12 cases as the confirmatory group), formulate their own hypotheses about their predictions, and then find ways to test them within the simulation. Additionally, the exploratory groups' 12 cases were situated within the context of a hypothetical college student experiencing ongoing health situations. This feature increased the possibility of personal relevance, another aspect of constructivist environments (Duffy & Jonassen, 1992).

• ***Results***: In examining the effects of group on conceptual change, six questions were identified from the pretest as posing conceptual problems for students (parallel items to these were included in the posttest). The exploratory (constructivist) group scored higher on four of the six parallel posttest questions, with two of the those four items being scored significantly higher. None of the six questions had a significant difference favoring the confirmatory group.

Regression on the posttest multiple choice score was calculated to determine the relative influences of variables and to identify any group X epistemological belief interaction. In the final regression stage, pretest score was the strongest predictor (Beta= .64, $p< .01$); treatment group was found to be significant (Beta= 1.15, $p< .03$) as well as epistemological belief (Beta= .32, $p< .05$). The interaction of group X epistemological belief was significant, with a Beta of -1.20 ($p< .03$). Members of the exploratory group with greater levels of epistemological sophistication performed better on the posttest, while members of the confirmatory group with lower levels of epistemological sophistication performed better on the posttest (Figure 2). Although the posttest concept comparison and the posttest multiple choice results were significantly correlated ($p< .01$), there were no significant results in regressing on posttest concept comparison score using the statistical procedure described above.

• ***Discussion***: The results of this study suggest the importance of learners' epistemological beliefs since these beliefs appear to interact with the type of learning environment in determining conceptual development. Students with greater epistemological sophistication did better in the exploratory simulation environment while students with less sophisticated beliefs about knowledge and learning achieved best in the more prescribed, confirmatory simulation environment.

Additionally, This study provided evidence that an exploratory (constructivist) simulation experience could be more effective in altering learners' misconceptions than a confirmatory experience. Allowing learners to create, test, and evaluate their own hypotheses in successive iterations satisfies conditions of conceptual change as theorized in the literature. Some evidence was obtained consistent with the view that providing learners with overly-detailed procedural instructions to solve problems in a simulated environment could be deleterious to conceptual change.

The natural class setting for this or any experiment helps support the intuitive external validity of the results. Many studies in computer-based learning have taken place in highly controlled environments; results obtained in such settings are harder to generalize to classroom settings in which cross-talk between computer stations and other interpersonal phenomena are common.

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Figures 1 and 2 on back...

(Confirmatory) Case #7: At rest, are there any significant differences between an fit and unfit individual concerning heart rate and/or stroke volume?

Stay on the STROKE VOLUME window. Change the figure to a "couch potato" and standing still; now click the GO icon; wait until the readings stabilize then record the stroke volume and heart rate here:

Change the figure to an athlete and standing still, now click the GO icon ,wait until the readings stabilize then record the stroke volume and heart rate here:

(Exploratory) Case #7: Lynn is disappointed in the results of the treadmill test and plans to begin exercising regularly. Lynn asks the doctor if a person who becomes an athlete will see a change in heart rate or stroke volume when at rest. At rest, are there any significant differences between an fit and unfit individual concerning heart rate and/or stroke volume?

Write your prediction here and explain briefly:

Now test your prediction with the simulation.
Briefly describe how you tested this case with the simulation, include specific numbers. State a conclusion.

Figure 1. Confirmatory and exploratory sample cases.

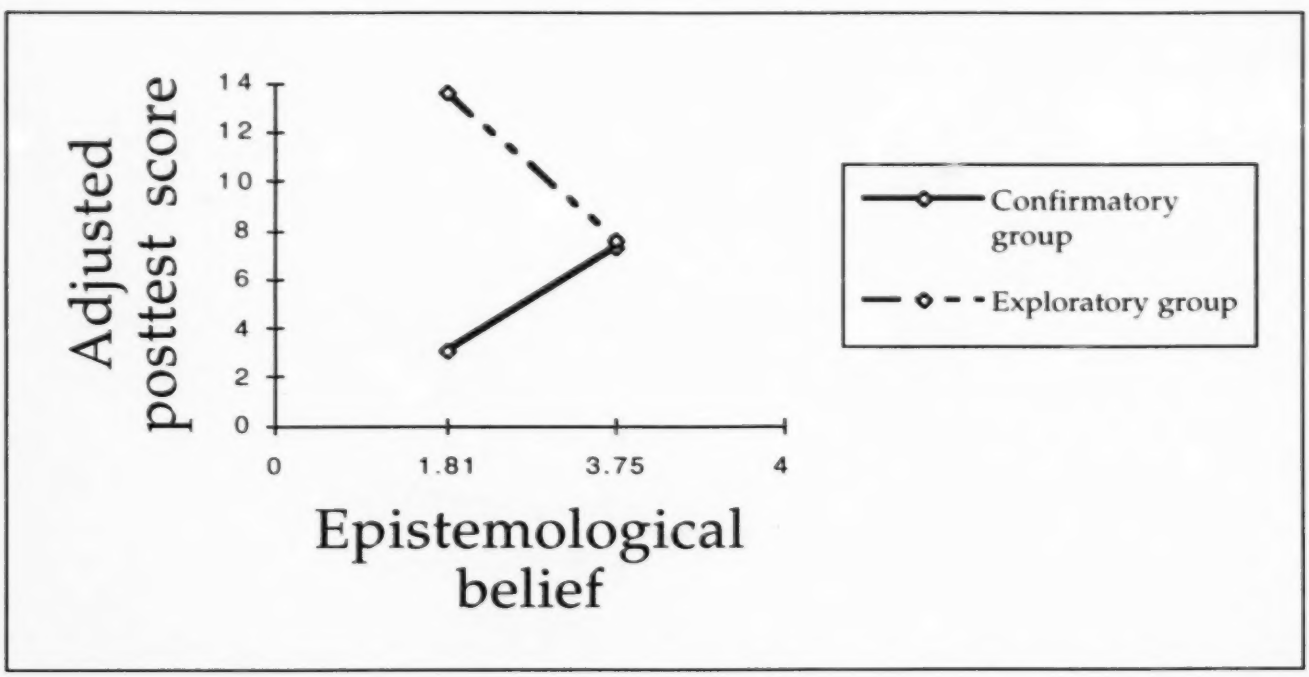

Figure 2. Two-dimensional projection of regression of posttest score on epistemological belief, with pretest score and section set to their means ***(higher epistemological values reflect less sophistication).